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Measurement of diurnal cosmic ray intensity variation at Calcutta with a meson telescope

BY (MRS) SARAMMA ALEXANDER and S. D. CHATTERJEE*

Department of Physics, Jadavpur University, Calcutta-32

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The diurnal and semi-diurnal variations of meson intensity have been measured at Calcutta (Geographical latitude 22°32′N and longitude 88°20′E at sea-level) with a meson telescope.

The diurnal variation has an amplitude of 0.13% with the time-maximum at 10.52 hrs I.S T which corresponds to 11 hrs. 13 min. local time. Similarly, the semidiurnal variation has been found to have an amplitude of 0.05% corresponding to a time maximum of 16 hrs 10 min local time.

The results have been compared with those obtained at various other places by other workers in the field.

INTRODUCTION

It is generally recognised that one of the fruitful methods of studying the influence of the solar field on cosmic rays reaching the surface of the earth is by analysing their diurnal and semi-diurnal variations Since the axis of rotation of the earth and its magnetic axis are inclined to each other, it is reasonable to expect that the anisotropy of cosmic rays incident on the earth will have different phase and amplitude at different stations on the same latitude. The collection of data on various parameters, including the time variations at different localities has been an accepted program in the study of cosmic rays.

The results of the study of data collected for Calcutta (Geographical latitude 22°32′N and longitude 88°20′E) during a period of nearly one and a half years during 1967-69, when the solar activity was at its peak for the present cycle, are given here. Another notable feature of scientific interest of Calcutta is its closeness to the Bay of Bengal, where geomagnetic anomaly is present, the significance of which in relation to a number of terrestrial phenomena has not yet been fully explained For collecting the data under study, a wide angle meson telescope of cubical geometry approximately following IGY specifications has been used. The hourly readings are corrected for atmospheric pressure variations and the corrected readings are subjected to harmonic analysis for the first five Fourier coefficients. Using the first coefficient, the amplitudes and time of maximum for the diurnal and semidiurnal variations are calculated and the results are represented on the harmonic dial.

*Present address: Indian Association for the Cultivation of Science, Jadavpur, Calcutta-32

Experimental

A wide angle triple coincidence meson telescope was set up for the present work. It has a cubical geometry of 2 ft $\times$ 2 ft $\times$ 2 ft subtending an angle of 45° with three trays having 15 Geiger counters in each. Between the bottom and middle trays there is a 10 cm thick lead filter. The Geiger counters have been locally fabricated from brass tubes of 2 ft length and $1\frac{1}{2}$ inches diameter with a wall thickness of 1/16 inch and filled with a mixture of argon and ethyl acetate to a pressure of nearly 9 cm of Hg so as to have a working voltage of about 1000 volts. The ends of the brass tubes are closed by means of brass plugs provided with central holes through which pass two narrow glass tubes to which the central filament is fused. Incidentally, the glass tubes also serve the purpose of insulating the central filament from the outer metallic tubes. The different components are assembled together and sealed by means of araldite resin.

Each counter is connected to a quenching unit consisting of 12AT7 univibrators. Fifteen such quenching units are accommodated in one tray and coupled to a cathode-follower tube EF91. The pulses from the three trays are fed to a Rossi coincidence circuit, the output of which is fed to a scaler having a scaling factor of 128 The final scaled output operates a mechanical recorder through a driver unit.

The power supply to the various electronic circuits (except the Geiger counters) are derived from electronically stabilized power packs. The high tension to the counters is obtained directly from a neon stabilized H.T. unit.

The hourly readings of the mechanical recorder along with corresponding times and dates are photographed simultaneously by means of an automatic camera operated by micro-switches and controlled by an external wall clock. The hourly ground pressure is recorded by a micro-barograph.

A negative voltage of nearly 1000 volts, depending upon the requirement of each counter, is fed to the brass tube of the Geiger counter which acts as the cathode. The central filament is connected to the plate of the quenching unit which is kept at a potential of nearly +300 volts when the counter is not working. Different counters having slightly different working voltages, are supplied from a voltage distributor from which any suitable voltage of 1000 ± 400V could be tapped.

The counter usually possesses a plateau of nearly 280 volts and the average life of a counter has been found to be nearly 10 months.

Harmonic analysis of results

Observations have been made for a period of nearly one and a half years starting from December 1967 to April 1969. Since the period under review was characterized by solar activities and geomagnetic disturbances, the readings of several days have had to be discarded on account of their large fluctuations. Readings for nearly 180 days have accordingly been chosen for the present analysis, which are corrected for the atmospheric pressure effect. A pressure coefficient of -0.17% per m.b. has been used for the usual correction. A sample of correlation analysis from a few months' data yielded nearly identical value for the pressure coefficient. The pressure corrected hourly values are next subjected to harmonic analysis for the first five Fourier coefficients from which the amplitude and time of maximum of the diurnal variation and semidiurnal variation are calculated using the following equation :

$$f(M) = \alpha_0+(\alpha_1 \cos \omega t+\beta_1 \sin \omega t)+(\alpha_2 \cos 2\omega t+\beta_2 \sin 2\omega t) \qquad \ldots \quad (1)$$

where, M = the hourly meson count

α_0 = the constant for the day

α_1, β_1 = the first harmonic coefficients

α_2, β_2 = the second harmonic coefficients

ω = the angular velocity *i.e.*, $2\pi/24$ in this particular case

and t = time

The first harmonic $(\alpha_1 \cos \omega t+\beta_1 \sin \omega t)$ can be rewritten as $A \sin(\omega t+\epsilon)$, where A represents the amplitude which is equal to $\sqrt{\alpha_1^2+\beta_1^2}$ and the time of maximum is when $\omega t+\epsilon = \pi/2$ *i.e.*,

$$\frac{2\pi}{24}+\tan^{-1}\frac{\beta_1}{\alpha_1} = \pi/2 \qquad \ldots \quad (2)$$

Similarly, the amplitude and time of maximum for the second harmonics are also calculated. The results are represented on a 24 hour harmonic dial for the diurnal variation and a 12 hour harmonic dial for the semidiurnal variation, following Bartels' (1935) method. Probable error circles are drawn on the harmonic dial using Bartel's (1932) method, with the 'centre of the cloud' as the centre and $P_i = 0.832\ M_i$, as the radius when $M_i = (\sigma_{\alpha_1}{}^2+\sigma_{\beta_1}{}^2)^{\frac{1}{2}}$ and $i = 1, 2, 3, \ldots$

$$M_i{}^2 = \frac{\Sigma(x_i{}^2+y_i{}^2)}{N}$$

the average square distance of each point from the centre of the cloud. The number of points within the circle is approximately the same as the number of points outside.

The amplitude of the diurnal of variation has been found to be 0.13% with the time of maximum at 10.52 hrs I.S.T. which is the same as 11 hrs 13 min local time. The amplitude of the semidiurnal variation is found to be 0.05% and the time of maximum at 16.10 hrs local time, respectively. Figures 1 and 2 represent the harmonic dials for the diurnal and semi-diurnal variations of cosmic ray intensity at Calcutta.

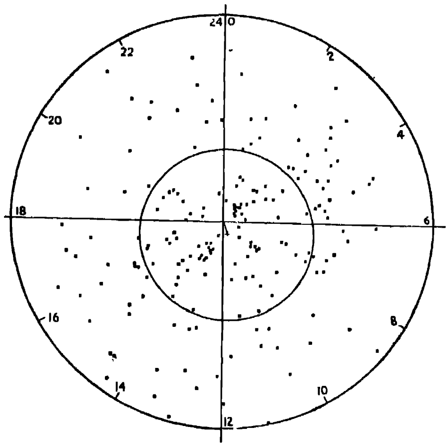

Figure 1. Harmonic dial with circle of standard deviation for diurnal variation of cosmic ray intensity

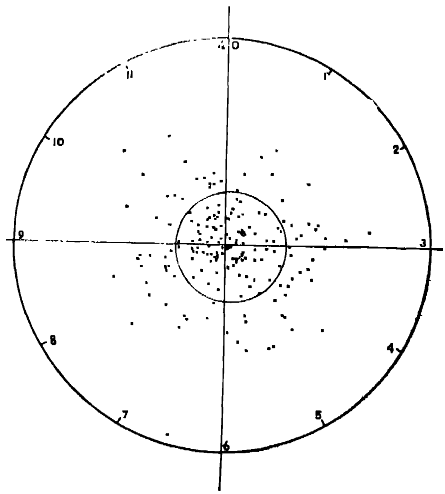

Figure 2. Harmonic dial with circle of standard deviation for the semi-diurnal variation of cosmic ray intensity.

Discussion

Since only one telescope has been used whose counting rate is scaled down to about 280 hours, the statistical error is found to be rather high.

The theoretical value of the time of maximum is about 18.00 hrs. According to Kane (1967) the geomagnetic bend would shift it by 2-3 hrs earlier in the case of the sea level mesons to about 15.00 hrs. In the present work the time of maximum of the diurnal variation is slightly earlier than the theoretical value which usually falls in the afternoon. One reason for the early occurrence of the time of maximum is that Calcutta is closer to the equator. Sarabhai *et al* (1955) while studying the daily variations at low latitudes using counter telescope data, observed that the time of maximum for diurnal variation comes earlier in lower latitudes. The actual monthly mean value of the amplitude for Ahmedabad varied from 0.22% to 0.71% and the time of maximum varied between 6.00 hrs, and 12 00 hrs. For the semidiurnal component, the amplitude varied between 0.02% to 0.26% while the time of maximum remained widely scattered. Forbush *et al* (1960) studied the diurnal and semi-diurnal variations for a period of 23 years (1937 to 1959) using ionization chamber data from Chetlenham, Huancayo and Christchurch applying statistical methods after correcting for atmospheric variations and got the mean value of the amplitude for the 1st harmonics as 0.12% and time of maximum at 13.48 hrs (L.T.) for Cheltenham, 0.15% and 10.40 hrs (L.T.) for Huancayo and 0 12% and 13.26 hrs (L T.) for Christchurch, while the second harmonic had the amplitude 0.036% and time of maximum 1.52 hrs for Cheltenham, 0.054% and 2.40 hrs for Christchurch.

Huancayo, being closer to the equator, has the time of maximum shifted towards earlier hours, as compared to other two stations. The present results of 0.13% and 11 hrs 13 min for Calcutta is comparable to Forbush's results for Huancayo which is at a still lower latitude than Calcutta.

Kanno (1961) has studied the data from 45 stations and found that the time of maximum of diurnal variation changes from 9.00 hrs to 18.00 hrs and it increases with the latitude. The effect is very prominent in the case of the sea level stations.

The solar activity during the period under study was very high which also might have contributed to the shift of the time of maximum to earlier hours. It is well known that such phase shifts of the variation take place during magnetically disturbed periods. Sarabhai *et al* (1955), Kane (1963) and Murthy *et al* (1965) observed that during high geomagnetic disturbances the times of maximum were shifted towards the earlier hours. Duggal *et al* (1962) noticed that during disturbed periods the diurnal variation vector had turned around the clock in 8 days.

Another factor that might have possibly influenced our time of maximum is due to the existence of geomagnetic anomaly in the Bay of Bengal (Malurkar, 1954).

The amplitude of the semidiurnal component is so small that many investigators expressed their doubts about its existence. Chatterjee *et al* (1955) obtained a value of 0.01% and showed that the value is statistically insignificant. Katzman *et al* (1960) studied the nucleonic intensity from 16 stations for a period of 5 years (1955 to 1959) and suggested that the semidiurnal component which was very small in most stations might have been due to the error in calculating the semidiurnal vector. Ahluwalia (1961) studied the data from Ahmedabad and Huancayo by separating the days on the basis of the daily *Cp* values and concluded that the low amplitude is due to the large variability of the time of maximum of the semidiurnal variation but that otherwise it is significant and is due to the anisotropy of the primary flux. Venkatesan *et al* (1967) found that the time of maximum for the semidiurnal wave is distributed reasonably well over all hours and suggested its origin as due to the transient changes in intensity. Laetti *et al* (1967) tried to explain the origin of the semidiurnal component as due to the fact that the spiral interplanetary magnetic field is much less highly wound at solar latitudes. According to their hypothesis, the galactic particles arriving along the Sun's polarfield lines may suffer much less modulation than those arriving in the ecliptic plane which would give rise to a second harmonic in the daily variation with the maximum at right angles to the direction of the spiral field.

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